14th ICCRTS

"C2 and Agility"

Intense Collaboration: Human and Technical Requirements for Agile C2

Dr. Elizabeth K. Bowman

U.S. Army Research Laboratory

Dr. Tim Pattison

Australia Defense Science and Technology Organisation

Mr. Denis Gouin

Defence Research & Development Canada-Valcartier

Point of Contact: Elizabeth K. Bowman

ARL-SLAD

AMSRD-ARL-SL-I

B. 390-A

Aberdeen Proving Ground, MD 21005

Telephone: 410-278-5924

E-mail Address: ebowman@arl.army.mil

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
JUN 2009		**00-00-2009 to 00-00-2009**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Intense Collaboration: Human and Technical Requirements for Agile C2	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **U.S. Army Research Laboratory,AMSRD-ARL-SL-I,B. 390-A,Aberdeen Proving Ground,MD,21005**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
In Proceedings of the 14th International Command and Control Research and Technology Symposium (ICCRTS) was held Jun 15-17, 2009, in Washington, DC

14. ABSTRACT
see report

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**40**	

Intense Collaboration: Human and Technical Capabilities for Agile C2

Abstract

Collaboration for Command and Control (C2) is becoming more intense in the Information Age. This is a result of the problems our leaders must confront; it is also the result of the burgeoning communications technologies available for their use. We present an emerging literature on intense collaboration (IC) and examine potential applications to military C2. We propose an integrated socio-technical approach that combines networked information technologies with individual and team work requirements. We offer one solution to IC spaces that utilizes integrated technologies designed to help people work together. Our discussion draws upon an international defense science workshop that focused attention on this issue and explored supporting technology capabilities. Participants experienced one IC environment and considered principles of team performance and group dynamics that could be applied to the design of such technologies. These insights into the process of IC are considered within the theoretical perspective of Agile C2 (Alberts & Hayes, 2003; 2006). Complex problems can be addressed by the design of enabling technology in support of a process for intense collaboration that manages and supports information collection, management, sharing and decision making.

Acknowledgements

This report was developed under the auspices of The Technical Cooperation Program (TTCP). The Command, Control, Communications and Information (C3I) Systems Group, Command Information Interfaces (CII) Technical Panel 2 (TP2) and Human Resources and Performance Group Human Aspects of Command (HUM TP11) collaborated in this effort. The groups collaborated to develop a report and host a workshop titled Intense Collaboration: Human and Technology Considerations for Military C2. The authors would like to acknowledge the HUM TP11 contributions of Dr. Joan Johnston, Chair, and Mr. Brian Donnelly, US Air Force member. We would also like to thank C3I TP2 members Mr. Don Monk, Dr. Greg Trafton, Dr. Peter Kwantes, and Mr. Peter Houghton. We would also like to acknowledge the participants who attended the Intense Collaboration workshop held in DRDC-Valcartier 9-11 September, 2008 in Quebec City, Quebec. These international defense scientists were gracious participants in the workshops and discussion groups that were central to developing the ideas presented in this paper.

Introduction

Military Command and Control (C2) operations are increasingly dynamic and complex both in terms of responding to problems and managing a multi-disciplinary, multinational force of military and civilian agents (McEver, Martin, & Hayes, 2008; Uruguay, Lessa & Santos, 2008). The nature of supporting networked communications technology and decision support systems available to all echelons of command further complicate the sensemaking and decision making process (Boury-Brisset, 2008; Walz, 2008). However, adding technologies to staff elements is not a purely additive process; technologies cause cultural and social impacts on users that alter the scope and pace of human activity (Schmidtchen, 2006, p. 10). Macklin, Phillips and Louvieris (2004) point out that organizations cannot rely on technology alone for innovation; processes and capabilities that focus on human activities and needs must drive the push for new technology. Recent examples from the conflicts in Iraq and Afghanistan, the tsunami in Indonesia, and hurricane Katrina provide illustrations of the complex nature of the C2 response and the need for careful integration of social and technological applications. What is needed is an integrated socio-technical capability to support intense collaboration (IC).

The term '*intense collaboration*' is only recently gaining attention in the business and scientific literature. Kumar, van Fenema and Von Glinow (2005) introduce the term with respect to globally distributed work teams in a business setting. Kumar et al. define collaboration intensity as follows (p. 131): "the required level and frequency of interactions needed for initiating and sustaining joint action and mutual awareness of the members of a team, the flux of activities in teamwork, the evolving work-object, and the context of the collaborative situation." The authors identify four concepts that impact the intensity of team collaboration. These are temporal arrangements of work processes, ease of sharing work, tightness of work coupling, and uncertainty of work. In our adaptation of the Kumar et al. concept shown in Figure 1, the center of the problem space depicts a low-intensity problem that is very procedural, is easy to understand by all parties, allows sequential access to work resources, and requires loose coupling among partners (e.g., work can be completed independently). As the work requirements move outward along the four vectors, the work product becomes more complex and the intensity of the collaboration required increases.

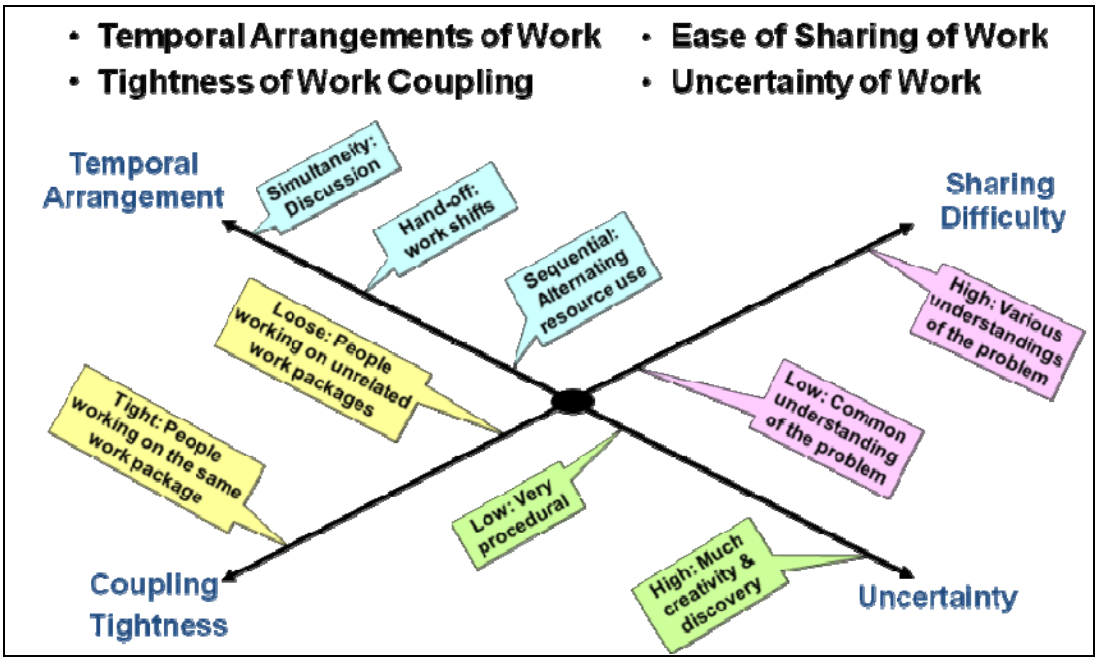


Figure 1 The Dimensions of Intense Collaboration (adapted from Kumar et al., 2005)

Military C2 teams are faced with problems of increasing intensity that are a result of both the nature of the presenting problems and the technology available for developing solutions (Alberts & Hayes, 2006). In our review of the literature, references to the need for and definitions of intensity of collaboration in this realm are present, but implicit. Smith, Grisogono & Clemente (2008) identify the need for team learning and adaptation that is complicated by the environment of full spectrum operations (e.g., major combat operations in one sector and stability and support operations in another) and the nature of teams that represent the "multiple arenas of government, nation, and coalition action" (p. 2). Hanlon (2008) notes the need for "enduring cooperation" in collaborative endeavors but leaves the specific form and extent of this cooperation unanswered. Ntuen (2008) makes the case for sensemaking as a critical element in information fusion for situational understanding in the complex C2 space of asymmetric warfare. He outlines the stages of the sensemaking process that would be relevant to a team collaboration (or, indeed, an individual task) effort.

In their extensive investigation of C2 in the 21st century, Alberts and Hayes (2006) identify several factors of Information Age C2 that relate to Kumar et al.'s (2005) schema of IC. First, they suggest that three key factors define the essence of transformed C2: "allocation of decision rights, patterns of interaction among the actors, and distribution of information" (p. 75). These factors can vary: allocation of decision rights can vary from unitary to peer-to-peer; interactions can be tightly constrained or unconstrained; and information can be tightly controlled or broadly disseminated (p. 75). Alberts and Hayes further consider the type of problem space demanding the attention of C2 teams. Problems can be described by the "rate of change, degree of familiarity, and strength of information position" (p. 77). If one considers this model with respect to the Kumar et al. representation of IC factors, "familiar" seems to be

similar to "uncertainty". We show a modified schema of IC showing the merged factors of the Kumar et al. and Alberts and Hayes models. The dashed lines are used merely to distinguish the new factor elements between the two models.

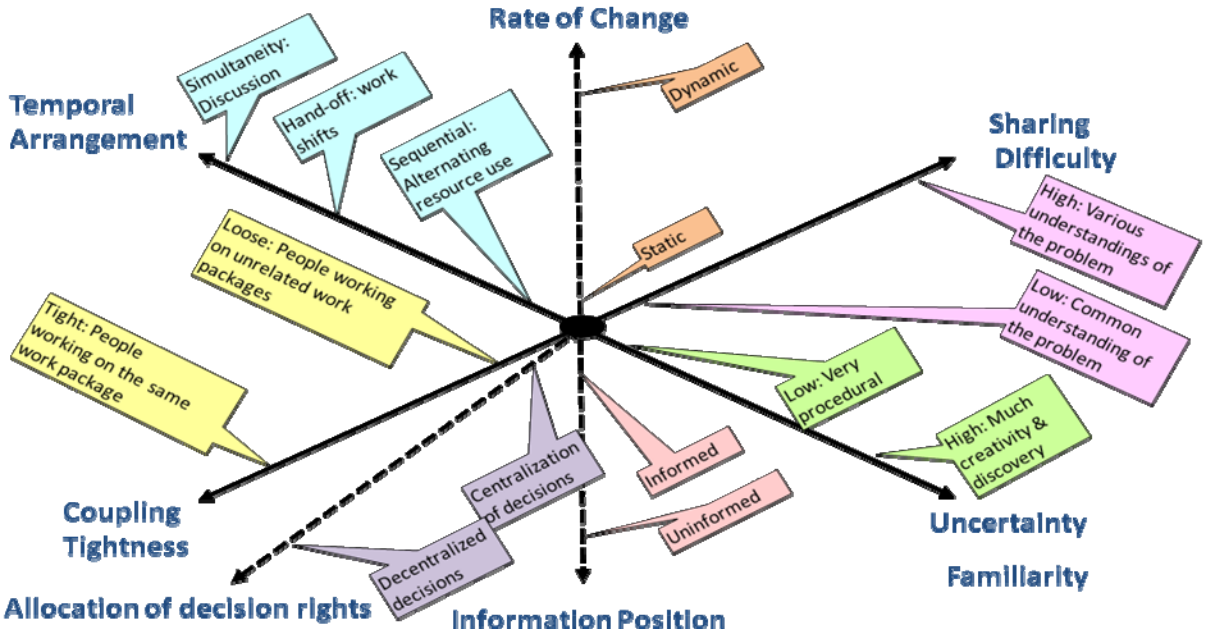


Figure 2 The Updated Dimensions of Intense Collaboration adapted from Kumar et al., 2005 and Alberts & Hayes, 2006

We briefly examine the ability of this schema of IC to describe current military scenarios. In his case study of the multi-level response to Hurricane Katrina, Moffat (2008) noted several factors in the immediate aftermath of the storm that relate to this structure. Consistent with the factors in Figure 2, Moffat noted coordination and information sharing difficulties among local, state, and federal officials in response to this very dynamic natural disaster. The high rate of change in storm conditions, combined with the lack of a unified C2 system, led to a reactive (and inefficient) deployment of resources. He also noted extreme uncertainty both in terms of the physical condition and exact location of response teams. These factors, in turn, affected the ability of multi-level responses teams to synchronize their actions through shared information. Certainly, the high level of uncertainty associated with this natural disaster was one feature of the problematic response.

We can extend this model to military responses to irregular warfare. Collaboration in these situations demands the rapid sharing of information with experts who are distributed in time and space, and who have different backgrounds and perspectives on the situation at hand. The ad hoc nature of these collaborative teams puts them at a disadvantage if they are unable to quickly develop task-knowledge coordination plans, communication patterns, and role structures (Eggenhofer, Huber, & Richter, 2008). We can expect that collaboration in these settings will,

for some extreme cases, meet the intense collaboration schema. That is, they will be increasingly characterized by dynamic, time pressured and uncertain problem domains where decision making is decentralized, information is sparse, and many perspectives on the solution space are present. In these cases, visualization technology that allows distributed team members to interact in ways that approximate face to face communications has been shown to aid team performance (Ntuen & Gwang-Myung, 2008).

Our focus in this paper is to examine the factors that contribute to the *intensity* of collaboration. In so doing, we will review one instantiation of a collaboration environment developed by the Australian Defense Science Technology Organization (DSTO) (Blackburn, Bright & Vernik, 2004; Pattison, 2008; Phillips, 2008) and shared with Defence Research & Development Canada (DRDC) (Gouin et al., 2007). The Livespaces collaboration environment described in this paper is defined as a "technology-enhanced collaboration space for a team of people. The purpose...is to integrate technologies that help people work together: to bring these technologies together into a supporting system that becomes part of the background, rather than the more common situation where these technologies appear as a set of disparate, idiosyncratic and quirky hardware gadgets and software applications" (Phillips, p.1).

This paper provides a review of IC and describes a practical solution of information software and hardware technologies shown to support distributed information sharing and decision making. We argue that this concept of intense collaboration provides support for the movement toward a military C2 structure that is agile with respect to individuals, organizations, and C2 systems (Alberts & Hays, 2003).

The findings presented in this paper are the results of a literature review and subsequent workshop hosted by The Technical Cooperation Program (TTCP) panels on Command Information Interfaces (C3I TP2) and Human Aspects of Command (HUM TP11) on Intense Collaboration: Human and Technology Considerations for Military C2 held 9-11 September 2008. Defense scientists and engineers from Australia, Canada, United Kingdom, and the United States engaged in focused discussions to investigate human and technology aspects of intense collaboration, develop an initial taxonomy for these types of settings, and identify a research agenda to mature this concept for military applications. These discussions were facilitated by the use of a collaboration environment established by DRDC Valcartier and running the Livespaces Operating System developed by Australia's DSTO.

Intense Collaboration and Agility

We consider that collaboration intensity is a matter of degree rather than kind. Our exploration of collaboration intensity will draw upon five factors: task, individual, team, individual environment, and team environment. The nature of the task requiring IC includes difficulty, novelty, complexity, time pressure, and dynamism. Individual factors focus on the

skills, experience, motivation, and engagement, physiological state and organizational context of the individual participants in the intense collaboration environment. The team context will draw upon the team's experience in working together, establishment of mutual trust, common purpose, spatial and temporal distribution, and shared or complementary skill sets. The individual environment we will consider includes access to information and tools required to perform a role and function, which could include reach-back to the parent organization. Finally, we consider the team environment that considers the access to tools to externalize and share information, the availability of groupware services, networked rooms and communication devices, and shared networking. Figure 3 shows this five factor model, in which the factors are nested and dynamically linked.

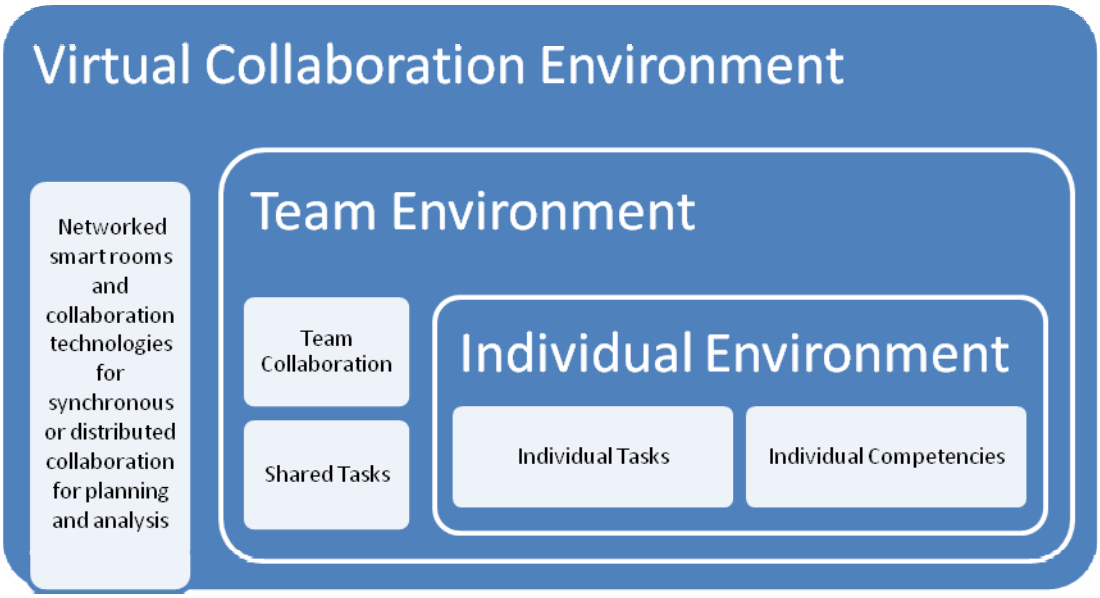


Figure 3 Five Factor Model for Intense Collaboration

The extent of C2 activities that depend on effective collaboration are witness to the importance this team behavior contributes to overall C2 decision making. With the emergence of Network Centric Warfare, collaboration has become a central issue in decision making and agile C2 (Hayes, 2008). C2 and Force Agility are introduced as emergent factors of action and decision synchronization. Agility is viewed as a transformational element for future forces and networked information and technologies are the enabler of this change (Alberts & Hayes, 2003). Agility has been conceptualized as a multidimensional capability enabling a military force to "change across the physical, information, cognitive, and social domains, and to achieve success in the face of the myriad changes that may occur" (McEver, Martin & Hayes, 2008, p. 1). Six attributes have generally been agreed to describe components of agility; these are robustness, resilience, responsiveness, flexibility, innovation, and adaptation (Alberts & Hayes, 2003; McEver et al., 2008).

The six dimensions of agility are robustness, resilience, responsiveness, flexibility, innovation, and adaptation and are defined in Table 1 (Alberts & Hayes, 2003). We will

consider these dimensions within the discussion of the five factor model of intense collaboration to investigate the potential contributions such a methodology provides to the goal of C2 agility. We suggest that the human and technical aspects of an intense collaboration environment support specific dimensions of C2 agility; it is this unique combination of socio-technical capabilities that allows agility.

Table 1 Agility attributes and associated definitions from Power to the Edge *(Alberts & Hayes, 2003)*

Attribute	Definition
Robustness	The ability to maintain effectiveness across a range of tasks, situations, and conditions
Resilience	The ability to recover from or adjust to misfortune, damage, or a destabilizing perturbation in the environment
Responsiveness	The ability to react to a change in the environment in a timely manner
Flexibility	The ability to employ multiple ways to succeed and the capacity to move seamlessly between them
Innovation	The ability to do new things and the ability to do old things in new ways
Adaptation	The ability to change work processes and the ability to change the organization

Intensity of Collaboration

Using our five factor model of IC as a starting point, participants at the Military Aspects of Intense Collaboration workshop were asked to consider factors that impact collaboration from task, team, and technology perspectives (this perspective included both individual and team IT environments). They were also asked to consider the context in which the intense collaboration occurs. This discussion was helpful in describing the characteristics of intense collaboration. Excerpts from these discussions are provided below, following relevant literature reviews that were used to stimulate discussion.

Nature of Intense Collaboration *Tasks*

Workshop participants were asked to consider task factors that might contribute to intensity. Examples of recent global crises used to stimulate this discussion included the Indonesia Tsunami, Hurricane Katrina, and strategic decision making in Operation Iraqi Freedom (OIF) and Operation Enduring Freedom (OEF) in Afghanistan. Intensity factors identified by the group included the type of task (i.e. planning, execution, negotiation), the time available for completing the task, and the nature of the problem at hand (i.e. interdependencies between tasks, novelty, personal risk involved). The group discussed the difficulty that emerging asymmetric problems pose to military decision makers in the form of high stake decisions that require access to distributed experts, information that may be difficult to procure and analyze, and choices between less than optimal courses of action. Also mentioned was the difficulty in

reaching consensus among divergent groups of stakeholders; and the realization that consensus may not be feasible.

Nature of Intense Collaboration *Individual Factors*

Using the characteristics of intense collaboration presented in Figure 1 and the agility attributes reviewed in Table 1, we can extract certain individual factors that will be required for the difficult nature of intense collaboration. We suggest that these include flexibility, resilience, innovation, and adaptation. Flexibility will be needed to respond to a variety of conditions and unfamiliar team partners. Resilience will be needed to rebound from failures that are likely to occur in the face of novel situations. Innovation and adaptability will be needed to 'think outside the box' in responding to unanticipated or unexpected scenarios. Some support for these suggestions are found in the team performance literature. Though these investigations were undertaken in environments that were not 'intense', we believe they can be useful to our purposes. In the following section, we highlight areas of interest for intense collaboration in italics.

Bonk and Wisher (2000) reviewed learner-centered psychological principles in their effort to understand collaborative and e-learning tools for use in military distance learning. Some of their findings are useful in exploring the intense collaboration setting from an individual user's cognitive and motivational perspectives. The authors found that learners had most cognitive success in on-line classes when the user could *create meaningful and coherent representations of knowledge over time*, could *link new information with existing knowledge in meaningful ways*, and could create and use a *variety of thinking and reasoning strategies to achieve goals*. Fiore, Cuevas, Scielzo and Salas (2002), however, caution that learners may be more or less adept at *monitoring their knowledge acquisition and comprehension process*. If individuals do not accurately estimate their situational awareness with respect to tasks, they may experience poor task performance. Given the complex nature of the tasks to be addressed in the IC environment, problem solving is likely to be a key enabler of performance. Oser, Gualtieri, Cannon-Bowers and Salas (1999) explore cognitive processes and skill areas that appear useful for effective problem solving. The areas that are most applicable to the IC environment include information processing, situation assessment, reasoning, and monitoring (Oser et al., p. 443). Of particular interest in the information processing skill area is the *ability to form problem templates that can be coordinated with team members* during task execution (Cannon-Bowers, Salas, & Converse, 1990). Templates that do not match or at least link at points with team members can lead to misinformation and lack of coordination. This is also an area that can be facilitated by IT, which will be discussed in a later section. In situation assessment, *understanding cues and patterns in the environment* are important; it is particularly critical to *understand the interactions among the cues to build causal relationships*. Intense and dynamic task environments challenge individuals to make decisions with imperfect information; this places a heavy burden on an individual's reasoning skills. Cannon-Bowers et al. suggest that flexibility and adaptability are important skills for success in such situations. Monitoring skills include the *ability to track individual, team, and system performance* (Canon-Bowers et al.).

Workshop participants concluded that individual factors would certainly impact intense collaboration settings. It was noted that a person's motivation and style of interaction would determine their ability and willingness to share information and participate in decision making activities. Considerations in this domain might include affect and personality (e.g. introversion vs. extroversion), response to stress, experience in the problem domain, and a shared background with other team members.

Nature of Intense Collaboration *Team Factors*

Intense collaboration describes tasks that are especially difficult and carry significant consequences of decisions. These teams will be comprised of members who are distributed by geographic regions, time zones, and organizational contexts. Team factors that we believe are important in intense settings include experience in working together, mutual trust, common purpose, and shared or complimentary skill sets. Brannick, Prince, Prince, and Salas (1995) further suggest that communication, cooperation and coordination are also related to team effectiveness. Highly effective teams share several attributes, among which are shared understanding of the task and others' responsibilities toward the task, a collective sense of efficacy (e.g., feeling they have what it takes to succeed), the flexibility to adjust resource allocations and work strategies, efficient implicit communication, and active monitoring of self and team performance (Levi & Slem, 1995; Stout, Salas & Carson, 1994). Under conditions of time pressure and stress, Zaccaro, Gualtieri, and Minionis (1995) found that task cohesion can improve team decision making.

Workshop participants considered team factors thought to be relevant to intense collaboration. These included organizational, group, leadership, and individual considerations. In distributed teamwork, it was recognized that tension may exist between organizational goals of the ad hoc team and the home agency, making it critical to establish liaisons with stakeholder groups. Tension may also exist if collaboration is occurring with teams of teams experiencing various levels of collaboration. In this case, explicit doctrine must replace implicit understanding because there will be less shared experience among the team members. Goal congruency issues may arise between the home organization and the collaborative team. This possibility relates to the Alberts and Hayes (2006) factor of allocating decision rights. The intense collaboration team will need to address issues of new and ad hoc members who represent different cultural and functional backgrounds; the team will need time to develop trust between members and in the team goals. Depending upon the structure of the team, operating constraints may arise, such as synchronizing meetings across time zones.

Given these constraints, leadership becomes a critical factor in intense collaboration settings. The leader may be expected to 'satisfice' among goals when competing considerations demand an adaptive approach. The leader will almost certainly need to span boundaries and achieve consensus from diverse groups, while being sensitive to team and individual member needs. Intense collaboration settings will make effective leadership difficult in many respects; one major reason is that such a team will have less implicit understanding of goals, activities, and

among team member motivations. The need to explicitly reason through process steps may be taxing and difficult.

Nature of Intense Collaboration *Internal/Team Environments*

Workshop participants were asked to consider two types of environmental influences on the IC setting; the external and internal (team) environment. The external environment is considered to be the reason for the collaboration; e.g., the tsunami, the hurricane, or the military conflict. The context of the problem stimulating the need for intense collaboration might include the type of mission (e.g. stability operations, humanitarian relief, and natural disaster services), resources available, and purpose of the intervention. The strategic goals of the collaboration will define the type of mission and the important stakeholders. Resources available would include time pressure, the unpredictability of events and consequences, the rapidity with which circumstances change in the environment, and how often updates are needed in the situation. Whether or not a common purpose exists between the team and the environment will affect the level of stress experienced by the team.

The internal environment can refer both to the individual and the team setting and is meant to describe the work spaces used in the collaboration. Two strategies were identified that may be of particular relevance to intense military collaborations. The first is real time remote interaction. This capability is supported by means such as teleconferencing, videoconferencing, video walls, collaborative group ware, desktop sharing, chatting, and other examples (Kumar et al., 2005). These communications require people to meet in real time; this presents problems if significant time differences exist between the locations. These methods also require team members to adjust their communication styles to the capabilities of the electronic media in use. However, this strategy does provide useful visual contact with remote team members and access to electronic data. This strategy would provide a robust capability to maintain effectiveness in a variety of conditions. The second useful strategy to enable intense collaboration is to use certain individuals as boundary spanning agents to connect different groups in the team. Cockburn and Highsmith (2001) have suggested that a team can be more effective in responding to change if it can reduce the cost of moving information between people, and reduce the elapsed time between making a decision to seeing the consequences of that decision. The authors noted that "The most important implication to managers working in the agile manner is that it places more emphasis on people factors in the project: amicability, talent, skill, and communication." This strategy provides an innovative solution to multi-disciplinary, heterogeneous, or large groups.

Technology for Intense Collaboration

Workshop participants were asked to participate in a discussion of how technology could be used for teams engaged in intense collaboration tasks. Considerations for services that would support intense collaboration focused on data collection, diagnostics, visualization capabilities, and communication services. In the data collection category, the retrieval, collection, sharing, and management of information were seen to be critical attributes to the IC process. It was noted

that some information would be difficult to obtain or assess given the complex nature of the asymmetric problem, and also due to information security concerns. Similarly, the analysis of large amounts of information could prove difficult and could demand certain types of data management tools. Related to the information collection problem is the capability to diagnose problems with servers. For example, in cases of natural disaster, local communication networks might be inoperable. Regardless of the location and nature of the problem, effective diagnosis is essential to quick repair. Tools that support shared situational awareness and decision making are essential for individuals and for the team. Considerations in this area would include identification of failure points, the assignment of thresholds for actions (to reduce cognitive load), the tracking and prioritization of goals, analysis of gaps in reaching goals, and synchronization tools. Communication tools will be required to allow team members to communicate with each other and with the population (e.g. an emergency broadcast system or access to key leaders in the community).

Australian Livespaces Collaboration Capability

In Network-Centric Warfare (NCW), distributed forces collaborate to achieve common objectives. To succeed, they must establish and maintain shared situation awareness, shared intent and coordinated action. These in turn require human collaborative activities such as information sharing, collective sensemaking, brainstorming, wargaming and consensus building.

To support these activities, nodes such as operational-level headquarters typically have dedicated meeting spaces fitted with videoconferencing equipment, networked computers, shared displays, whiteboards and document viewers. A range of groupware technologies is also available to support communication and information sharing amongst the members of a distributed team, as well as the collaborative development of artifacts such as documents. A shared information environment with domain-specific applications is essential, along with reachback access by liaison and component staff to their home information environments and personnel.

The physical and virtual workspaces which collaborators jointly inhabit must be designed and dynamically reconfigured to support the required collaborative activities. Configuration of a meeting room requires the control of devices such as lights, projectors, interactive surfaces and videoconferencing hardware, as well as physical rearrangement of devices and furniture. Configuration of a virtual workspace may include the enrolment of new participants, the assignment of roles such as document editor or floor controller, and the customization of shared information repositories and collaborative fora. Collaborators might also be empowered by the meeting convenor to place information onto shared displays for discussion and joint interaction.

The interfaces through which such configuration is effected should minimize the distraction of collaborators from the collaborative task. Preset configurations which can be rapidly customized to the requirements of the current collaboration are worthwhile. Modern

meeting rooms offer increasingly integrated control of devices, which can be combined with smart-room technologies such as voice control to further simplify configuration of the environment.

A collaborative workspace can also provide services to its occupants, such as digital capture, transcription and replay of audiovisual proceedings, spoken dialogue or handwritten text to facilitate information sharing and recall amongst collaborators.

The Australian Defence Science and Technology Organisation (DSTO) has demonstrated enhanced integration, automation and inter-connection of collaborative workspaces through a network of client battlelabs running the Livespaces Operating System. Figure 4 depicts a precursor to one of these battlelabs.

Figure 4 Precursor to one of the Australian battlelabs running the Livespaces Operating System. This collaborative planning environment includes public displays, individual workstations, whiteboards, and maps.

A Livespace (Blackburn et al., 2004; Phillips, 2008; Pattison, 2008) is an integrated collaborative workspace consisting of purpose-built furniture, power and networking infrastructure, and a variety of devices including lights, projectors, video matrices, computers, interactive surfaces, and videoconferencing hardware. The Livespaces Operating System integrates these into a coordinated whole, and federates them with Livespaces at other locations to provide a distributed, smart-room environment for synchronous collaboration.

Users experience features such as voice-, touch-panel and desktop-controlled room automation, desktop sharing, shared interaction with public displays, information sharing, meeting transcription and location-based services. Software developers benefit from ready-made infrastructure for collaborative applications and scalable distribution across wide-area networks.

Recently, the Livespaces Operating System was offered to the Defence R&D Canada for evaluation and collaboration (Gouin et al., 2007). The goal of the Canadian initiative is to define

a consolidated set of specifications for a collaborative working capability aimed at the Operational Command and Fusion Centers. In support of this objective, DRDC has established several collaborative workspaces which, like the Australian battlelabs, include software tools and selected groupware tailored to the application domain.

Role of Technology for Intense Collaboration

Participants at the workshop were asked to examine the role that technology should play to support intense collaboration environments. The group considered the range of hi-tech tools available and whether or not these supported specific collaboration tasks. Figure 5 shows a workshop artifact that captured the range of technology tools that could be used in a collaboration setting.

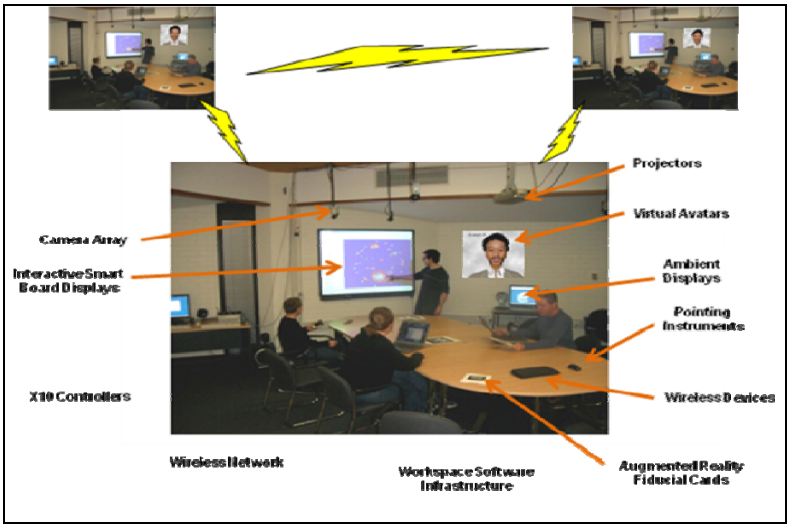


Figure 5 Types of Hi-Tech Tools available for Intense Collaboration

The discussion group began the consideration of how technology could assist in the intense collaboration environment with a review of how humans and machines compare with respect to task accomplishment. This review noted that humans surpass machines at detecting small amounts of visual/acoustic energy, perceiving patterns of light or sound, can improvise and be flexible in choosing procedures, are capable of storing large amounts of information for long periods and can recall relevant facts, can reason and exercise judgment. On the other hand, machines surpass humans at responding quickly to control signals, can apply great force smoothly and precisely, can perform repetitive and routine tasks, can store information briefly and erase it completely, can reason deductively and computationally, and can handle highly complex operations at once (Parasuraman, Sheridan, & Wickens, 2000).

The participants agreed that current collaboration systems exist that provide a common workspace for team members and includes a repository for shared documents with the following tools: email, instant messaging, video and audio conferencing, and screen sharing. Three questions were posed to begin the focused discussion on supporting technology:

- What else is needed to support people conducting distributed, net-centric operations in a Global C2 Enterprise environment?
- How does one enable distributed teams to interact with the directness, informality, and flexibility typical of small cohesive teams or organizations?
- How does one enable intense collaboration with mission partners from other commands, agencies, and nations?

General discussion supported the premise that the 'science of control should not hinder the art of command.' An important feature of intense collaboration is the frequent movement from a personal space to a shared space. Individual control of shared spaces is not a trivial matter and is primarily a matter of business rules among the team. This is because anyone could take control of the shared space as they needed to; experience shows that simple requests for control are usually adequate for sharing control. The workshop group made several suggestions for how technology could add to the intense collaboration experience. The suggestions are listed below.

- Convert text to graphics (e.g. Create geo or conceptual views that help us come to a shared understanding)
- Visualizations of concept maps of things that are being discussed can help people "see" the issues more clearly and therefore may help prompt further discussions
- Create systems that mix narrative and graphics to explain concepts and relationships
- Create a system which records keywords and concepts that have been discussed and links them back to the audio of the meeting that referred to these things
- Need to support people joining meetings part way through (e.g. find a way of summarizing what has been said so far)
- Use wordnet to explore different meanings of words to expand and contract on what people are referring to
- Need the ability to disagree (e.g. need technology to support alternatives - need to hold disagreements and not prune branches too early - allow people to explore braches perhaps as separate subgroups)
- Support for electronic water cooler – allowing teams to share information informally
- Information Technology is critical to organize, archive, collaborate and share in a workspace environment

While these suggestions should be considered in future design requirements, the group was concerned that technology can hinder human collaboration. Specifically, the following considerations were brought to light.

- Individual workspaces tend to individualize work
- Some people will just choose not to use the technology - and these can be a real hindrance for a team trying to use collaboration technology
- Latency can be a real concern and disturbs collaboration
- Variation in latency may be a worse problem - because you do not know when it will respond

- Amount of bandwidth consumed to support collaborative technology may exceed what is possible
- There will be different technical support to different parties - some are disadvantaged and this will cause significant discontinuities in the collaboration – for example, are there alternatives to having high quality video?
- Tendency to feel that you can trust more if you can see people
- Value of the human cues – collaboration software can eliminate many of them or not convey them – the closer you approach high end VTC the more comfortable people are
- Discrepancies exist between body language and the spoken word

The discussion group concluded that new technologies could improve the intense collaboration environment if caution was exercised in selecting and deploying these tools. They suggested several considerations for leaders in this area. They advised that the right technology be selected for the right task. For example, tasks that involve more complexity require more cues. This would suggest that a negotiation task could benefit from video input compared to less complex tasks that could use text only modalities. In today's world, they mentioned that people need "natural" interfaces; requiring multi-sensory collaboration and interfaces with very little latency. Good collaboration uses graphics and stories; these require specialized products. Finally, they noted the ad hoc nature of collaboration sessions, with players joining and leaving the group. This process argues for some type of history player and automatic recapping of task progress.

Using the understanding of intense collaboration environments developed in the workshop, we propose an initial mapping between team, leader, and technology components with the six dimensions of C2 Agility (see Table 1).

	Intense Collaboration Dimensions		
	Team Factors	**Leadership Factors**	**Technology Factors**
Agility Attribute			
Robustness	Task-sharing among team members ; institutional memory would be developed over time and with technology support	Leadership may need to be shared among team members; more than one leader may be needed	Redundant technologies to provide back-up capabilities for information sharing and data management; quick recall of past actions to aid new problems
Resilience	Development of shared knowledge and trust would allow members to shift/share workload as needed to address unexpected issues	Leader efforts to make explicit knowledge implicit over time would lead to continuity in performance	Diagnosis and repair of inoperable technologies; tools that provide updates to members joining an ongoing process

Responsiveness	Timely responses can be effected by 24-7 operations across time zones; diverse expertise would allow the team to address a wide range of issues	Leader should monitor external and internal environments for early detection of cues that would impact team operations	Tools that alert team members to threshold conditions
Flexibility	Diverse expertise would provide a variety of approaches in responding to issues and needs	Leader should actively work to achieve consensus among stakeholders while avoiding 'group think' among team members	Employment of visual, audio, textual forms of communication with a variety of display capabilities (white boards, knowledge walls, etc.)
Innovation	Team members with diverse cultural, political, and educational backgrounds can design new approaches to team problems/issues	Leader should span organizational and cultural boundaries	The presence of networked communication technologies may stimulate the operators to use the tools in novel ways; the presence of an IT expert will aid this process (people innovate, not tools)
Adaptation	Team member diversity would lead to a variety of responses to situations	The Leader may have to 'satisfice' among goals and be creative in determining courses of action	See above comment

Table 2 Mapping of Agility Attributes with Intense Collaboration Factors

The team, leader, and technology components identified as supporting the intense collaboration setting would support Agile C2; however, the realization of such an intricate technology-rich IT environment would take considerable effort to design, man, and maintain. The benefits of such a capability should continue to be explored by the international defense community. Workshop participants concluded the discussion of intense collaboration by identifying relevant research questions that might assist in this continued exploration.

The focus group assigned to explore future research areas in the realm of intense collaboration chose to divide the range of questions into four areas: taxonomy, people, process, and technology. The questions from these areas are presented in Table 3. These questions reflect a wide range of research interests that should stimulate cross-discipline exploration.

Factor	Research Question
Taxonomy	1. What is intense collaboration and how do we measure it? 2. What are the components of intensity? 3. What are the components of collaboration? 4. What are the effects of expertise? 5. What are the factors that make up intense collaboration
Team Behavior	1. How do we explore the hardening of teams as they gain experience with each other? 2. What are the effects of expertise? 3. Is the solution better by a group or by an individual? 4. Does collaboration enhance the creativity of commanders? Under what circumstances? 5. When does nominating a leader, and under what circumstances, assist in solving the problem? 6. How does the number of individuals affect the team, with the same amount of work, and the need and style of collaboration? 7. To what extent is competition a good driver for collaboration? 8. Is anonymity needed for successful accomplishment of certain team tasks? 9. What is the effect of collocation vs. distribution on collaboration? 10. What is the effect of private information on team collaboration?
Team Process	1. How do we measure the difference between process and outcomes? 2. What are the components of intensity? 3. What are the components of collaboration? 4. What is intense collaboration and how do we measure it? 5. What types of tasks requires collaboration? 6. How is collaboration related to Collaborative Decision Making?
Technology	1. How does the feature and ease of sharing a screen (full screen/subsection) enable/disable collaboration? 2. Does collaboration technology enhance/malign team behavior? 3. Under what circumstances are information sharing vs a shared space to work (shared reading is not collaboration, shared writing is) beneficial? 4. How do interactive collaboration technologies support the dynamic needs of a distributed decision making team (in intense collaboration)? 5. How does the ebb and flow of roles and process affect the use and the effectiveness of collaboration and of the collaboration technology? 6. Do collaboration technologies assist in the team shift transition problem? 7. How does latency of technologies affect team use of the tools? 8. What level of IT presence is required in the collaboration – from VTC to other lesser forms of presence? 9. What does tool familiarity do to the workload and team effectiveness? 10. To what extent does the technology create false expectations of what is achievable?

Table 3 Proposed Intense Collaboration Research Questions

Conclusions

The need for military teams to engage in intense collaboration in distributed, ad hoc settings is not new. What is new is the consolidation and integration of advanced communication and information technology to support these intense team processes. The rapid growth and sophistication of information technology tools allows military leaders to harness new capabilities to enable intense collaboration across the globe with nearly the same performance results as face-to-face meetings. It is important for scientists to understand not only the behavioural components of such teamwork but to also define technology that can support these team processes. The Livespaces functionality provides a proof of concept for the further development of these environments that can support intense collaborative teamwork. The strength of these capabilities is that the collocation aspects become more transparent, which is critical in the joint, interagency, multinational and public enabled collaborative environment of the future. The experiment in Fall 2008 between Australia, Canada, United Kingdom and the United States through the TTCP was an important first step in this direction.

The mapping of the team, leader, and technical factors derived from the intense collaboration process onto the six dimensions of C2 Agility provide insight into how such a collaboration environment should be shaped and designed. Each of the six dimensions are critical elements of overall agility and each demands a particular type of response from the human participants and the technology tools chosen to support the process. At times, some of these dimensions could be in opposition to one another (for example, as a team is struggling to become familiar with technology, innovation and adaptation may be confusing and counterproductive). The research questions developed by workshop participants capture a wide range of relevant considerations that, when examined in more detail, should make it possible to advance this capability in defense environments for the benefit of leaders and teams.

The concluding session of the workshop captured key points for military leaders to consider in examining the concept of deploying intense collaboration environments that are supported by networked communication technologies as described in this paper. It was noted that intense collaboration is a human activity that must be supported by transparent technology; tools that demand constant attention will detract from the nature of the human activity. To provide an intense collaboration capability for agile military C2, technology applications must mature to better support these requirements. Multisensory interactive technologies will enhance awareness of remote site members in a distributed collaboration. Psycho-social issues of leadership, teamwork, and team process must be considered in the development of intense collaboration technology. Experimentation is recommended to determine how best to develop interactive collaboration technologies to support the dynamic needs of a distributed decision making team.

References

Alberts, D. S. & Hayes, R. E. (2003). Power to the Edge: Command and Control in the Information Age. Washington, D.C.: CCRP.

Alberts, D. S. & Hayes, R. E. (2006). Understanding command and control. Washington, D.C.: CCRP.

Blackburn, T., Bright, D. & Vernik, R. (2004). Evaluating procedural aspects of intense collaboration. ACM International Conference Proceeding Series, Vol. 82 , Proceedings of the third Nordic conference on Human-computer interaction.Tampere, Finland, 323 – 326.

Bonk, C. J. & Wisher, R. A. (2000). Applying collaborative and e-learning tools to military distance learning: A research framework. (Technical Report). Alexandria, VA: Army Research Institute for the Behavioral and Social Sciences.

Boury-Brisset, A-C. (2008). Concepts and technologies for a knowledge environment supporting situation awareness. Proceedings of the 13th International Command and Control Research Technology Symposium, Bellevue, WA, June 17-19.

Brannick, M. T., Prince, A., Prince, C., & Salas, E. (1995). The measurement of team process. Human Factors, 37(3), 641-651.

Cannon-Bowers, J.A., Salas, E., & Converse, S. (1990). Cognitive psychology and team training: Training shared mental models of complex systems. Human Factors Society Bulletin, 33(12), 1-4.

Cockburn, A. & Highsmith, J. (2001). Agile software development: The people factor. Software Management, November. [On-line]. Available: http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=963450&isnumber=20799

Eggenhofer, P., Huber, R., & Richter, S. (2008). Communication processes and patterns in high-performing networked teams: A qualitative analysis. Proceedings of the 13th International Command and Control Research Technology Symposium, Bellevue, WA, June 17-19.

Fiore, S. M., Cuevas, H. M., Scielzo, S. & Salas, E. (2002). Training individuals for distributed teams: problem solving assessment for distributed mission research. Computers in Human Behavior 18, 729-744.

Gouin, D., Fortin, R., Chouinard, L., Dion, V., St-Germain, V., Forest, A. & Dewar, C. (2007). Initial LiveSpaces deployment in JIIFC Det planning room (Star Top Road – Ottawa).

(Technical Note DRDC Valcartier TN 2007-300) . Valcartier, Canada: Defence R&D Canada.

Hanlon, B. (2008). Enhancing cooperation in complex endeavours through quantum information exchange. Proceedings of the 13th International Command and Control Research Technology Symposium, Bellevue, WA, June 17-19.

Hayes, R. (2008). Thoughts on Collaboration. Briefing presented at the meeting of The Technical Cooperation Program (TTCP) Workshop on Intense Collaboration, September 9-11, 2008, Quebec, Canada.

Kumar, K., van Fenema, P.C. and Von Glinow, M.A. (2005). Intense collaboration in globally distributed work teams: Evolving patterns of dependencies and coordination. Managing Multinational Teams: Global Perspectives Advances in International Management, Vol 18, 127–154.

Levi, E. & Slem, C. (1995). Team work in research and development organizations: The characteristics of successful teams. International Journal of Industrial Ergonomics, 16, 29-42.

Macklin, C., Phillips, P. & Louvieris, P. (2004). Lessons learned from commercial transformations to network centric operations. Proceedings of the 9th International Command and Control Research Technology Symposium, Copenhagen, Sweden, Sep 14-16.

McEver, J. G., Martin, D. M., & Hayes, R. E. Operationalizing C2 agility: Approaches to measuring agility in command and control contexts. Proceedings of the 13th International Command and Control Research Technology Symposium, Bellevue, WA, June 17-19.

Moffat, J. (2008). The response to hurricane katrina: A case study of changing c2 maturity. Proceedings of the 13th International Command and Control Research Technology Symposium, Bellevue, WA, June 17-19.

Ntuen, C. (2008). The process of sensemaking in complex human endeavors. Proceedings of the 13th International Command and Control Research Technology Symposium, Bellevue, WA, June 17-19.

Ntuen, C. & Gwang-Myung, K. (2008). A sensemaking visualization tool with military doctrinal elements. Proceedings of the 13th International Command and Control Research Technology Symposium, Bellevue, WA, June 17-19.

Oser, R. L., Gualtieri, J. W., Cannon-Bowers, J. A., & Salas, E. (1999). Training team problem solving skills: An event-based approach. Computers in Human Behavior 15, 441-462.

Parasuraman, R., Sheridan, T. B., & Wickens, C. D. (2000). A model for types and levels of human interaction with automation. IEEE Transactions on Systems, Man, & Cybernetics - Part A: Systems and Humans, Vol.30, No. 3., 286-297.

Pattison, T. (2008). LiveSpaces heritage and pedigree. Briefing presented at the meeting of The Technical Cooperation Program (TTCP) Workshop on Intense Collaboration, September 9-11, 2008, Quebec, Canada.

Phillips, M. (2008) Livespaces Technical Overview. Defence Science and Technology Organisation, Technical Report DSTO-TR-2188.

Schmidtchen, D. (2006). Eyes wide open: Stability, change and network-enabling technology. (Working Paper No. 129). Australia: Land Warfare Studies Centre.

Smith, E. A., Grisogono, A-M., & Clemente, M. (2008). Cajole and coordinate: C2 in a complex security environment. Proceedings of the 13th International Command and Control Research Technology Symposium, Bellevue, WA, June 17-19.

Stout, R. J., Salas, E., & Carson, R. (1994). Individual Task Proficiency and Team Process Behavior: What's Important for Team Functioning? Military Psychology, 6(3), 177-192.

Uruguay, A., Lessa, N. & Santos, C. (2008). C2OLISEU-A meta model for research and development of complex network centric operations. Operationalizing C2 Agility: Approaches to Measuring Agility in Command and Control Contexts. Proceedings of the 13th International Command and Control Research Technology Symposium, Bellevue, WA, June 17-19.

Walz, E. (2008). Situation analysis and collaborative planning for complex operations. Proceedings of the 13th International Command and Control Research Technology Symposium, Bellevue, WA, June 17-19.

Zaccaro, S., Gualtieri, J. & Minionis, D. (1995). Task Cohesion as a Facilitator of Team Decision Making Under Temporal Urgency. Military Psychology, 7(2), 77-93.

Intense Collaboration: Human and Technical Requirements for Agile C2

Elizabeth Bowman
Tim Pattison
Denis Gouin

14th ICCRTS June 2009

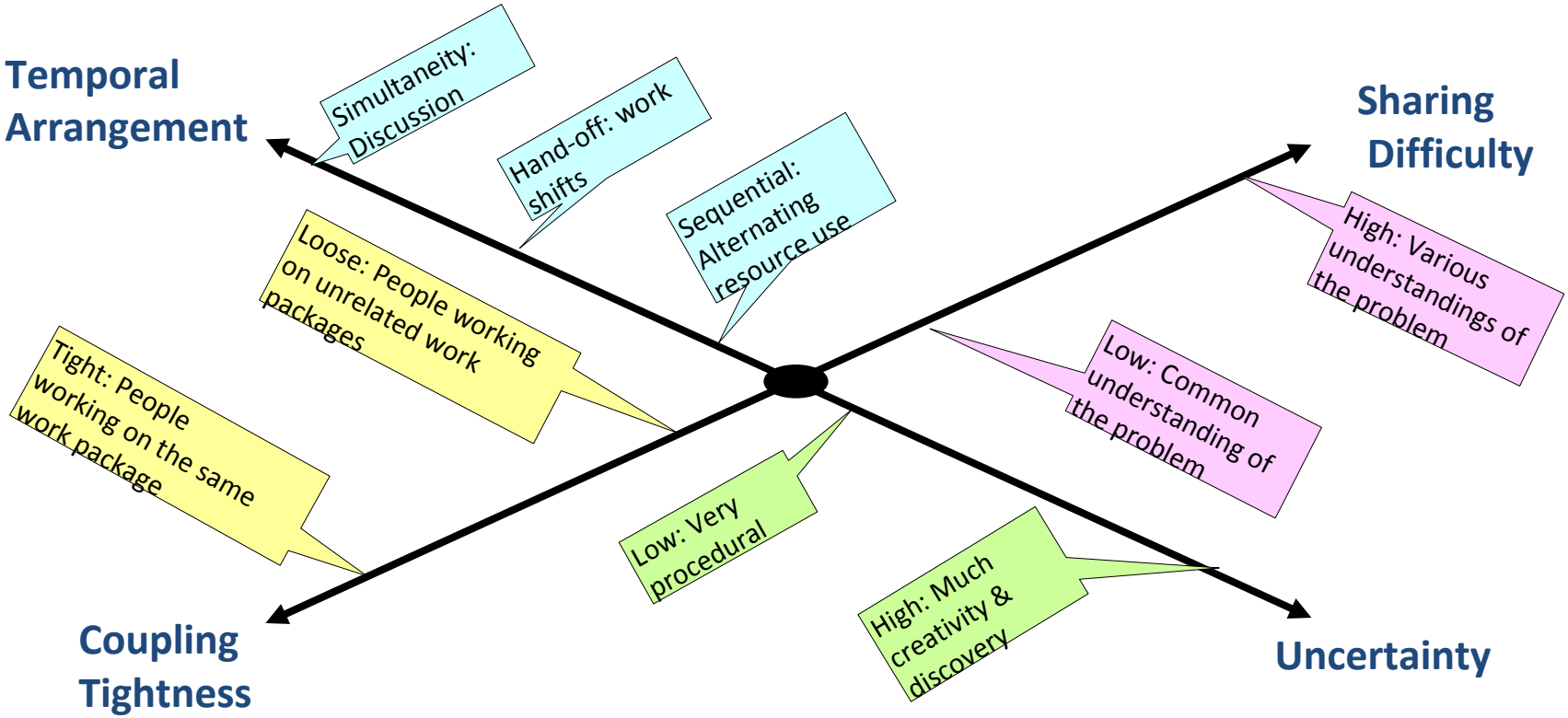
Acknowledgements

This report was developed under the auspices of The Technical Cooperation Program (TTCP). The Command, Control, Communications and Information (C3I) Systems Group, Command Information Interfaces (CII) Technical Panel 2 (TP2) and Human Resources and Performance Group Human Aspects of Command (HUM TP11) collaborated in this effort. The groups collaborated to develop a report and host a workshop titled Intense Collaboration: Human and Technology Considerations for Military C2. The authors would like to acknowledge the HUM TP11 contributions of Dr. Joan Johnston, Chair, and Mr. Brian Donnelly, US Air Force member. We would also like to thank C3I TP2 members Mr. Don Monk, Dr. Greg Trafton, Dr. Peter Kwantes, and Mr. Peter Houghton. We would also like to acknowledge the participants who attended the Intense Collaboration workshop held in DRDC-Valcartier 9-11 September, 2008 in Quebec City, Quebec. These international defense scientists were gracious participants in the workshops and discussion groups that were central to developing the ideas presented in this paper.

Why Intense Collaboration?

- Increasing complexity of problems facing military and civilian leaders
- Burgeoning communications technologies that allow networked collaboration, drive expectations, and also enables enemy activities.
- Need to adapt human aspects of IC to technological capabilities and affordances.

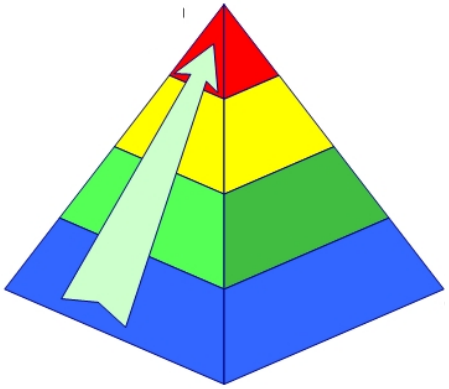
Intense Collaboration Defined (1)



"The required level and frequency of interactions needed for initiating and sustaining joint action and mutual awareness of the members of a team, the flux of activities in teamwork, the evolving work object, and the context of the collaborative situation (Kumar, Fenema & VonGlinow, 2004, p 131).

Adapted from Kumar, Fenema, and Von Glinow, *Intense Collaboration in Globally Distributed Teams: Evolving Patterns of Dependencies and Coordination*. (June 2004, 08). ERIM Report Series Reference No. ERS-2004-052-LIS. Available at SSRN: http://ssrn.com/abstract=594988

Collaboration Intensity Dimensions



Time and Space of Collaboration

Maturity levels of Collaboration

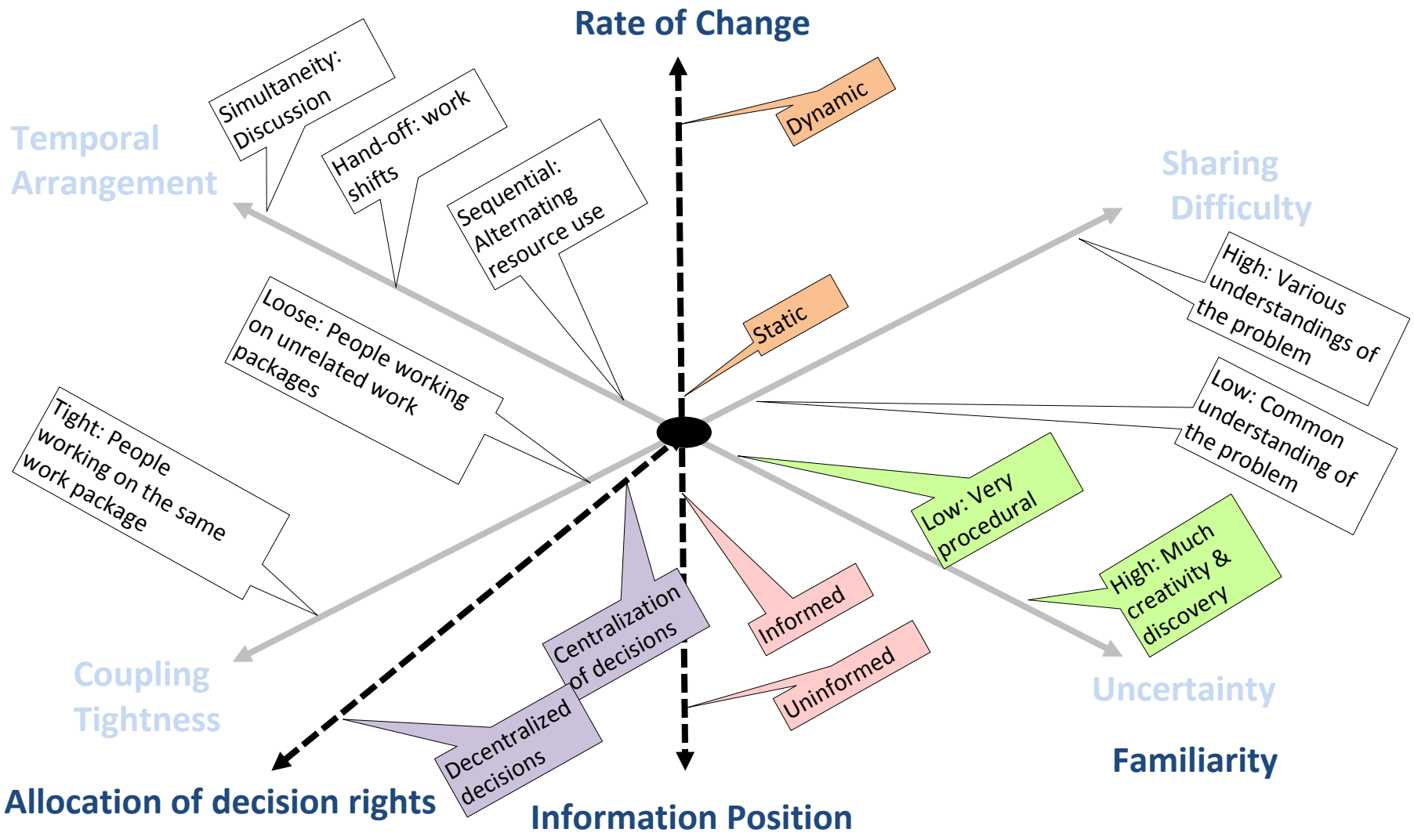
Nature of Collaboration

Time and Space Collaboration is taking place in both time and space dimensions. Each of these aspects provide distinctive characteristics that details further such collaboration and influence how collaboration takes place and is executed amongst participants;	▪ Same time / Same place ▪ Same time / Different place ▪ Different time / Same Place ▪ Different Time / Different place
Nature Participants' particular relationships amongst each others is another key characteristic that has influence on the collaboration process;	▪ Symmetry of Knowledge Relationship ▪ Functional Relationship of Organization ▪ Number of Participants
Maturity Levels The purpose of collaboration is another aspect that qualifies further the collaboration process. Specific criteria are associated in maturity assessment of the collaboration process	▪ Shared objectives/end-state among participants and sense of urgency. ▪ Formal communication processes (protocols). ▪ Commitment and sense of belonging. ▪ Open communication, interoperability among participants, mutual trust and respect. ▪ Complementary, diverse skills and knowledge, intellectual agility and autonomy of thinking:

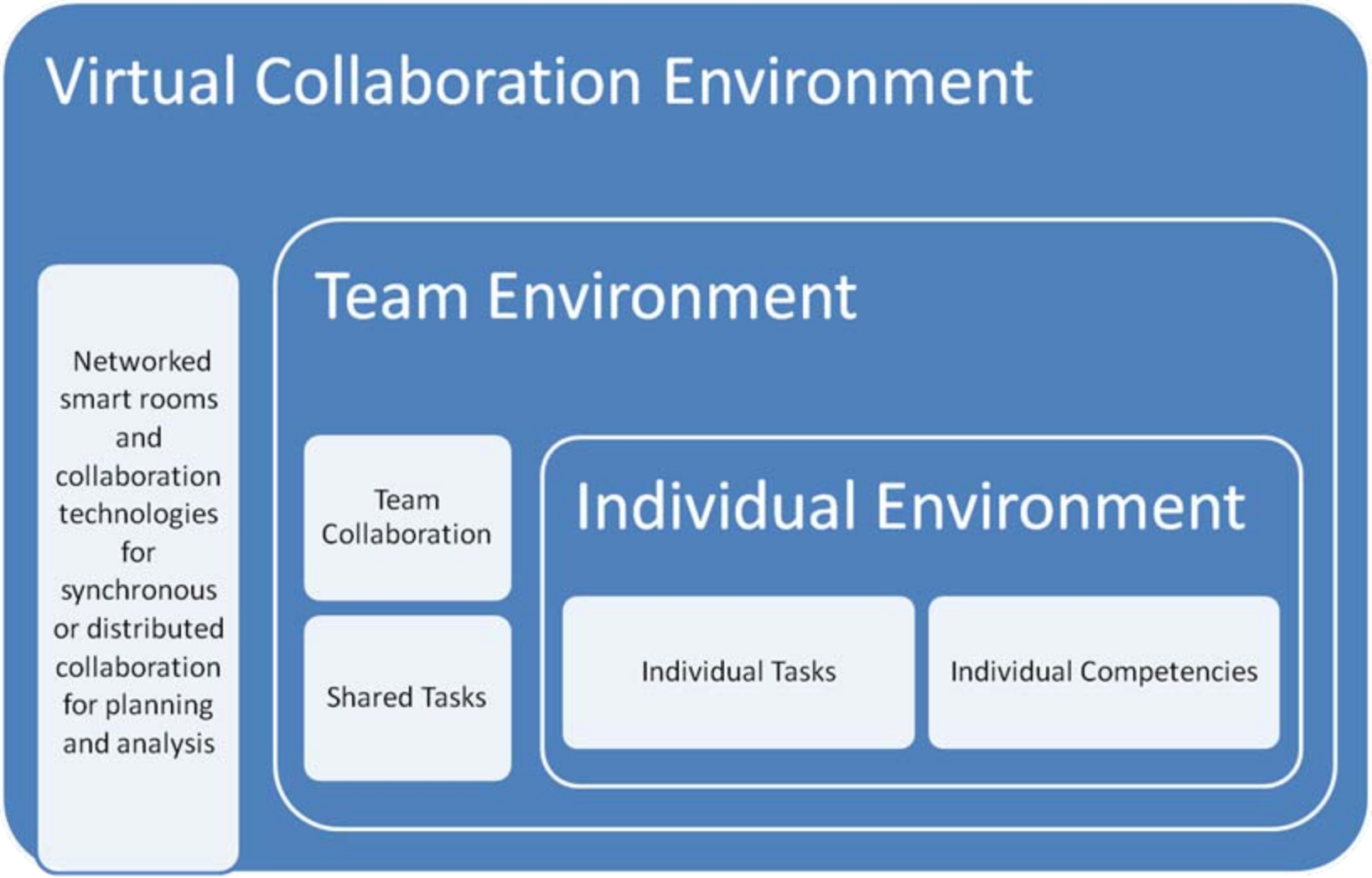
Adapted from Bureau and Pelletier, *LiveSpaces Collaborative Working Enabling Technology Operating Concepts Study Version 3.0*. May 2007). JCDS 21 Information and Knowledge Technologies Domain

Examples of Intense Collaboration

Intense Collaboration and Information Age C2



Intense Collaboration and Agility



IC: Tasks

- Task Types: planning, execution, negotiation
- Time available
- Nature of problem at hand
- Emerging asymmetric problems pose high-stake decisions requiring access to remote experts, large data sets that are difficult to procure/analyze, and choices between less than optimal courses of action.
- Difficulty in reaching consensus among divergent stakeholders; consensus may not be feasible.

IC: Individual Factors

- Flexibility:
  - Respond to a variety of conditions and unfamiliar/shifting team partners
  - Create meaningful/coherent knowledge representations over time
  - Understand cues and patterns in novel environment
  - Understand interactions among cues to build causal relationships
- Resilience:
  - Rebound from failures that will occur in novel situations
  - Form problem templates to coordinate with new members
- Innovation/adaptability:
  - Think creatively in unanticipated/unexpected scenarios
  - Link new information with existing knowledge
  - Use a variety of thinking/reasoning strategies to achieve goals
  - Track individual, team, and system performance

IC: Team Factors

- Experience working together
- Mutual Trust
- Common Purpose
- Shared/complimentary skill sets
- Leadership
- Collective sense of efficacy
- Flexibility to adjust resource allocations and work strategies
- Active monitoring of self and team performance

IC: Internal/External Environments

- External:
  - Strategic goals: mission type, stakeholders
  - Resources available: time pressure, unpredictability of events and consequences, rapidity of change
  - Common Purpose: will impact stress level
- Internal:
  - Real time remote interaction (VTC, TC, groupware)
  - Use individuals as boundary spanning agents to connect various groups in the team

Technology for Intense Collaboration

How should technology support collaboration?

Camera Array

Interactive Smart Board Displays

X10 Controllers

Projectors

Virtual Avatars

Ambient Displays

Pointing Instruments

Wireless Devices

Wireless Network

Workspace Software Infrastructure

Augmented Reality Fiducial Cards

Livespaces: AU Intense Collaboration

Affordances

- **Convert text to graphics**
  - **Create geo or conceptual views that help us come to a shared understanding**
- **Visualisations of concept maps of things that are being discussed can help people "see" the issues more clearly and therefore may help prompt further discussions**
- **Create systems that mix narrative and graphics to explain things?**
- **Create a system which records keywords and concepts that have been discussed and links them back to the audio of the meeting that referred to these things**
- **Need to support people joining meetings part way through**
  - **Find a way of summarizing what has been said so far**
- **Use wordnet to explore different meanings of words to expand and contract on what people are referring to**
- **Need ability to disagree**
  - **Need technology to support alternatives - need to hold disagreements and not prune branches too early - allow people to explore braches perhaps as separate subgroups**
- **Support for electronic water cooler – allowing teams to share information informally**
  - **could just ping a few people separately using current Livespaces sticker functionality**
- **The IT is critical to organize, archive, collaborate and share in a workspace environment**

Hindrances

- Individual workspaces tend to individualize work
- Some people will just choose not to use the technology - and these can be a real hindrance for a team trying to use collaboration technology
- Latency can be a real concern and disturbs collaboration
- Variation in latency may be a worse problem - because of variability in response
- Amount of bandwidth consumed to support collaborative technology
- There will be different technical support to different parties - some are disadvantaged and this will cause significant discontinuities in the collaboration - are there alternatives to having high quality video?
- Tendency to feel that you can trust more if you can see people
- Value of the human cues – collaboration software can eliminate many of them or not convey them – the closer you approach high end VTC the more comfortable people are
  - Discrepancies between body language and what is being said

Intense Collaboration and Agility

	Intense Collaboration Dimensions		
	Team Factors	**Leadership Factors**	**Technology Factors**
Agility Attribute			
Robustness	Task-sharing among team members ; institutional memory would be developed over time and with technology support	Leadership may need to be shared among team members; more than one leader may be needed	Redundant technologies to provide back-up capabilities for information sharing and data management; quick recall of past actions to aid new problems
Resilience	Development of shared knowledge and trust would allow members to shift/share workload as needed to address unexpected issues	Leader efforts to make explicit knowledge implicit over time would lead to continuity in performance	Diagnosis and repair of inoperable technologies; tools that provide updates to members joining an ongoing process
Responsiveness	Timely responses can be effected by 24-7 operations across time zones; diverse expertise would allow the team to address a wide range of issues	Leader should monitor external and internal environments for early detection of cues that would impact team operations	Tools that alert team members to threshold conditions

Intense Collaboration and Agility

Flexibility	Diverse expertise would provide a variety of approaches in responding to issues and needs	Leader should actively work to achieve consensus among stakeholders while avoiding 'group think' among team members	Employment of visual, audio, textual forms of communication with a variety of display capabilities (white boards, knowledge walls, etc.)
Innovation	Team members with diverse cultural, political, and educational backgrounds can design new approaches to team problems/issues	Leader should span organizational and cultural boundaries	The presence of networked communication technologies may stimulate the operators to use the tools in novel ways; the presence of an IT expert will aid this process (people innovate, not tools)
Adaptation	Team member diversity would lead to a variety of responses to situations	The Leader may have to 'satisfice' among goals and be creative in determining courses of action	See above comment